EXPERIENCES AND LESSONS LEARNED IN PROJECT RISK MANAGEMENT

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ABSTRACT

The paper describes a state-of-the-art computer-based project risk analysis technique which has been in widespread use since 1970. The technique has been used to assist in management of project risks on over a hundred projects worldwide, with a total value of over $55 billion. PROMAP V* resembles conventional deterministic project management tools only in that it uses the conventional critical path network as the framework for a project risk model. The model is then analyzed to determine the interrelated schedule and cost risks resulting from time, cost, and technical performance uncertainties. At the same time, the model serves in the usual way the routine functions of project estimating, planning, scheduling, resourcing, costing, and control.

BACKGROUND AND INTRODUCTION

In 1963 and 1964, as a consequence of a number of significant Defense program overruns, the RAND Corporation investigated the analytical assumptions of the PERT project management tool which had been utilized on an increasing number of DOD programs over the previous five-year period. The results of the research 1.) revealed that a major shortcoming of the critical path technique is that because it is deterministic it does not adequately account for the impact of uncertainties on project time and cost performance. As a consequence, PERT-based schedules and time-related estimates of costs are inherently optimistic, and project overruns are being inadvertently built into the project plan from the very start.

Almost twenty years later, the Defense systems acquisition community now finds itself in the very peculiar circumstance of continuing to support widespread use of deterministic project management tools on one hand, while on the other, attempting to cope with the problems of increasingly complex acquisition programs by sponsoring development of a proliferation of special-purpose analytical tools designed specifically to deal with project risks and uncertainties.

1.) See References 5, 9, 10 and 11.

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Project management has been employed on DOD programs for some time, but until recently, it has been largely non-rigorous. The original PERT was intended to rigorously deal with uncertainties affecting project time and cost performance, and at that time, it was described as a "stochastic" technique because it accepts range estimate inputs which account for uncertainty. But, the range values are reduced to a single "expected" value and the subsequent critical path analysis is deterministic. Hence, the benefits of probabilistic analysis are not realized.

At UCLA, in 1966, we started development of a probabilistic network analysis package designed specifically for projects where uncertainties are significant. By 1968, we were applying the first operational versions of PROMAP (Project Risk Management and Planning) on Navy ship overhaul projects. Early application results were reported in the Navy Management Review, April/May 1969 issue.

Navy applications continued on ship acquisition, modernization, and repair projects and in 1975, at the Fourth Annual DOD Procurement Research Symposium at Colorado Springs, I described the PROMAP approach and compared it with conventional deterministic techniques with the aid of explicit results.

The following year, the PROMAP technique was included in the Naval Sea Systems Command project management handbook, Reef Points, Later in 1976, I presented a paper at the Fifth Annual DOD Procurement Research Symposium at Monterey, covering application of PROMAP to government contract claims analysis.

Further applications on DOD and non-Defense projects in aerospace, energy, transportation, and construction fields led to continuing improvement in the PROMAP approach, and in 1981 as Panel Chairman at the Air Force Risk and Uncertainty Workshop at Colorado Springs, I discussed the advanced features of the latest version, PROMAP V.

Over the 15 years since it became operational, the PROMAP V technique and its predecessors have been successfully applied to over a hundred large, complex Defense and non-Defense projects, with a total value in excess of $55 billion.

THE PROMAP V* APPROACH

The foundation of the PROMAP V* approach is the Project Risk Model which is in effect, the conventional critical path activity network, modified to include logic and data accounting for uncertainties in (see Figure 1):

Internal Factors

- Planning (including contingency planning)
- Technical performance
- Time performance
- Resource performance
- Cost performance
- System support readiness

External Factors

- Economic factors
- Funding
- Environmental factors
- External deliverables

By accounting for the various types of uncertainty in a single model, the computer analysis accomplishes the intricate correlations among the different uncertainty factors and schedules and costs, which is so necessary for a reliable assessment of project risks. Data inputs are accepted from a variety of reliable data sources and estimating approaches, including empirical data and parametric, engineering, analogy, factor, and subjective estimating techniques.

In conducting a project risk analysis with PROMAP V*, the project model is "run" (simulated) in the computer as many as several hundred times; each run representing a complete project realization from start to end, with activity paths, activity durations, resource requirements, and costs sampled from distributions contained in the input data.

The results include project schedules and schedule risks, costs and cost risks, and resource requirements, together with data on critical activities, diagnostics, graphics, and other management information.

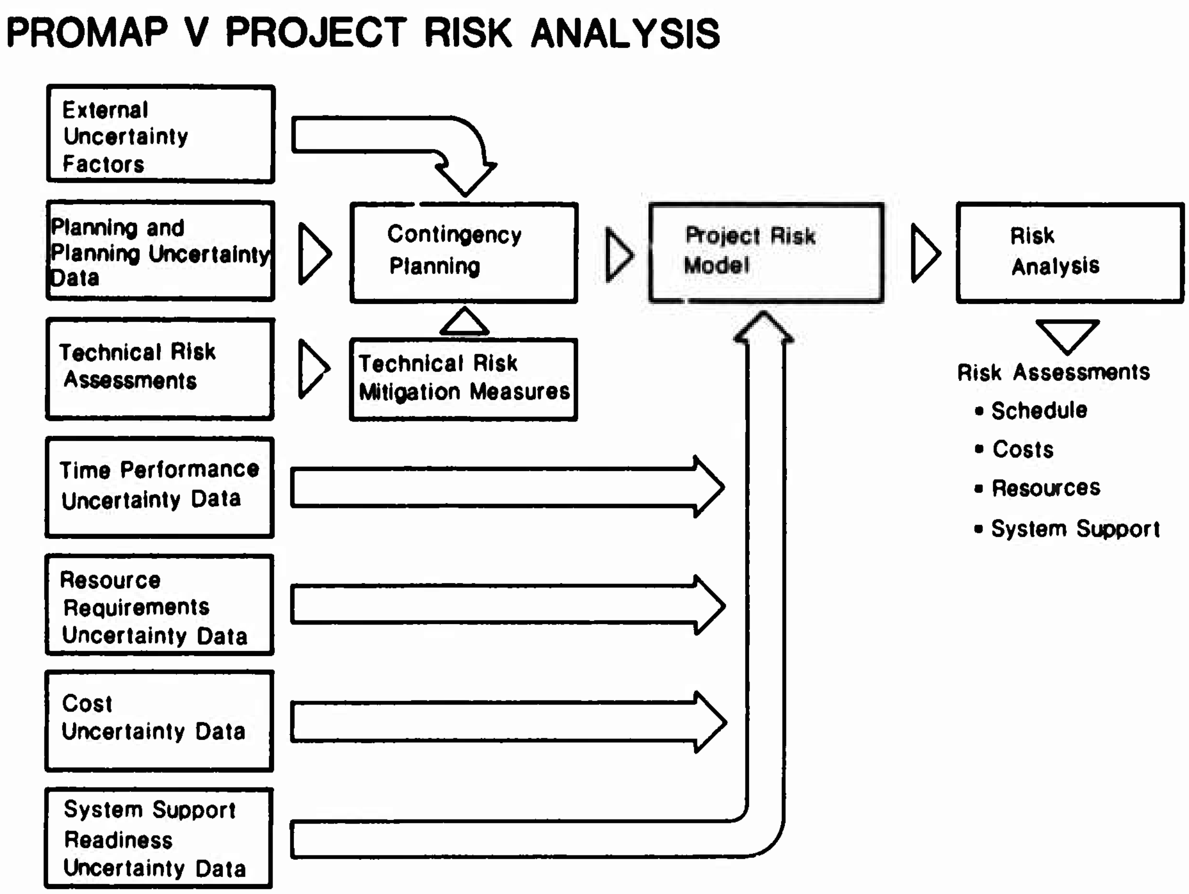

Figure 1. PROMAP V* PROJECT RISK ANALYSIS

A. Planning and Contingency Planning

The conventional critical path network (project plan), identifies all project activities from start to completion. Activities are arranged in proper sequence of performance, depicting their interrelations and interdependencies. Conventional, deterministic techniques are limited to representing each activity at a 100 per cent likelihood of occurrence.

A key feature of the PROMAP V* technique is its ability to account for uncertainty in the project plan. For example, a set of operational specifications may or may not be returned to the preparer for revisions. Or certain software design features may or may not be rejected by the Project Manager and returned for modification; a "backup" plan may be undertaken to substitute a less advanced state-of-the-art system feature should the primary design effort prove to be unsuccessful; or weather may delay an important field test.

If the program plan, schedule, costs, and resource requirements are to be realistic, such uncertain actions must be accounted for in terms of their likelihood of occurring.

As an example, Figure 2 illustrates a project plan incorporating a contingency plan consisting of Activities 5 and 8, representing a "back-up" in the likelihood that upon completion of Activity 2, the primary plan to develop an advanced state-of-the-art system feature (Activities 4, 7) will be assessed to be too risky. At the start, it is assessed that the primary plan has an 80% probability of technical success. Accordingly, the "back-up" plan is assigned a 20% probability of being implemented. This is referred to as "Contingency Planning."

As another example, suppose Activity 6 is a key test of a critical subassembly. Based on past experience, it is estimated that there is a 90% chance that the test will be successful (Activity 9) and a 10% likelihood that it will fail and the subassembly will have to undergo some modifications and retest (Activity 10). This situation is depicted by showing Activity 9 as having a 90% probability of occurring, and Activity 10 a 10% probability of occurring.

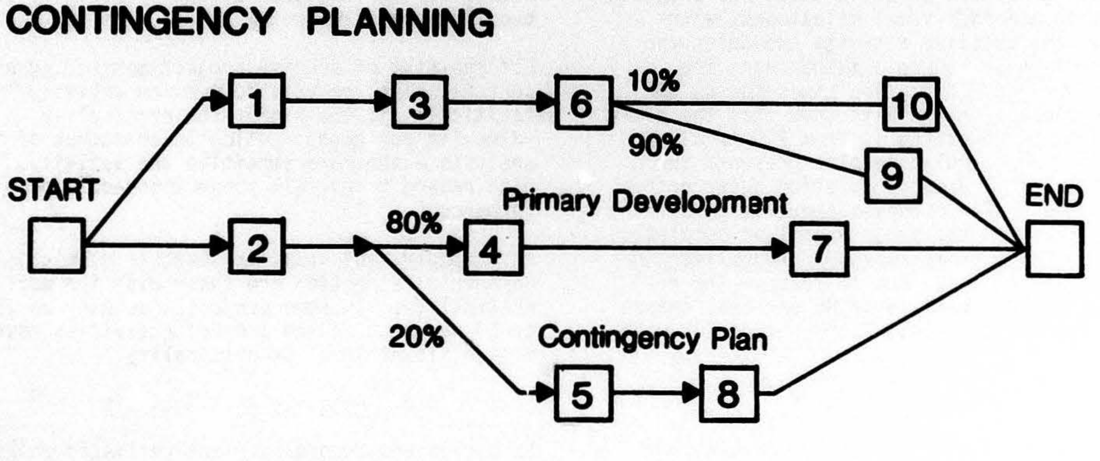

Figure 2. Contingency Planning

B. Technical Risk Management

Uncertainties and risks inherent in technical or software development can have major impact on the likelihood of attaining project objectives.

In the typical case, the technical risk elements are identified and the risks assessed. Conventionally, for technical risk elements which are critical to project success, management attention is directed at minimizing the impact on project performance. With PROMAP V*, "contingency" plans designed to mitigate the risks are developed and included as part of the overall project model. Typically, contingency planning may include measures such as early starts, allocation of additional resources, redundancy, and substitution of proven state-of-the-art technology.

During the course of the project, as the technical development proceeds, periodic reviews are made to obtain a current risk assessment of the technical risk elements.

It is normally expected that the risk level for an individual development item will decrease as the work progresses. However, should the updated risk assessment indicate that the technical risk level has not adequately decreased since the previous assessment, the appropriate measures are taken to accelerate implementation of related contingency plans; the objective is to provide assurance that project objectives are attained despite the continued existence of technical risks.

C. Schedule Risk Analysis

Schedule risk analysis results include the range of times covering the span between the earliest and latest possible dates for project completion and individual milestones, with accompanying detailed activity schedules and schedule risks. Figure 3 illustrates the range of project completion times for an example project. The results show that the project might be completed in from 240 to 330 workdays. The cumulative plot presents the probabilities of project duration between the two extremes. For example, there is a 90% probability that the project will be completed in 300 workdays or less, a 60% probability in 280 workdays or less, and so forth. The results show that there is an 85 per cent chance of overrunning the schedule target of 260 workdays.

Activity Criticality

One of the misleading aspects of conventional deterministic methods is the assumption that there is a single "critical" (longest time) path which determines the duration of the project. The designated critical path then becomes a focal point for project management.

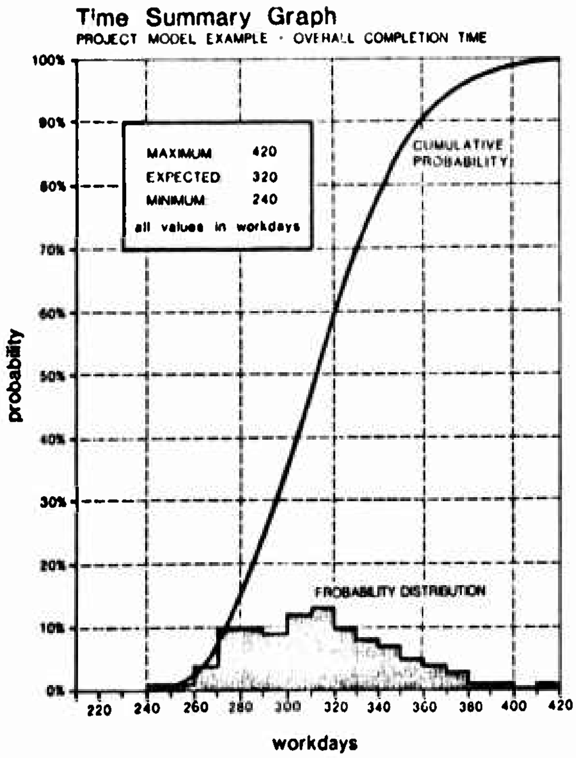

Figure 3. Time Summary Graph

However, when uncertainty factors are accounted for, there can be a number of different network paths which have significant probability of becoming critical during the course of the project. In fact, a probabilistic analysis will usually demonstrate that the "longest time" path of the deterministic technique has significantly less than a 100% probability of becoming critical.

For the sake of precise project monitoring and control, risk analysis focuses on activity "criticality"; the higher the criticality value (in per cent) - which is an output of the analysis - the more sensitive the activity, with regard to overall project schedule performance.

Accordingly, the activities requiring close managerial attention are those with the most criticality. On some projects, as many as 35 to 50 per cent of the project activities have a significant level of criticality.

D. Resource Risk Analysis

Schedules and budgets are not realistic unless the resources required to accomplish the individual project activities are available when needed. Resources may include personnel, materials, documentation, equipment, facilities, funds, or suitable environmental conditions.

Most projects suffer from some scarcity of resources--the net effect can be to significantly delay the project completion and add to the project cost.

PROMAP V* provides the project manager with resource requirements, taking into account the variable start and finish dates of the activities.

Figures 4 and 5 show the difference between deterministic and probabilistic resource analyses. The deterministic results in Figure 4 show a one-day peak requirement of nine General Maintenance Men; Figure 5 shows a probabilistic requirement of none for as long as twenty days. The difference is due to the cumulative impact of uncertainties in the probabilistic case.

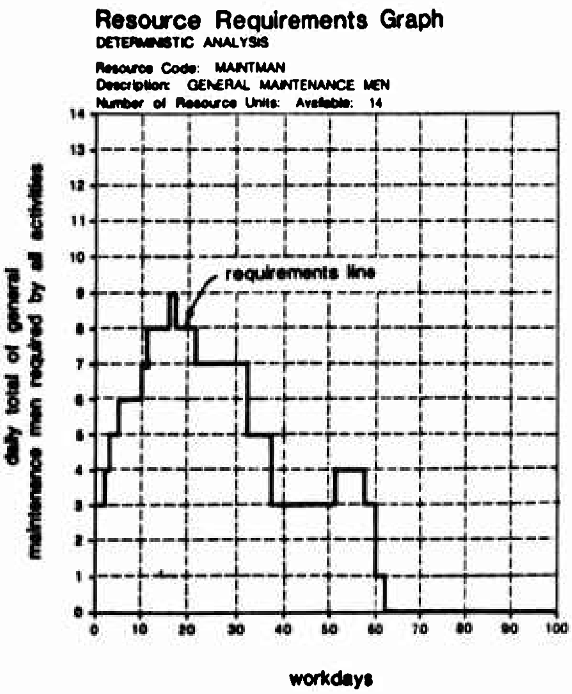

Figure 4. Deterministic Resource Requirements

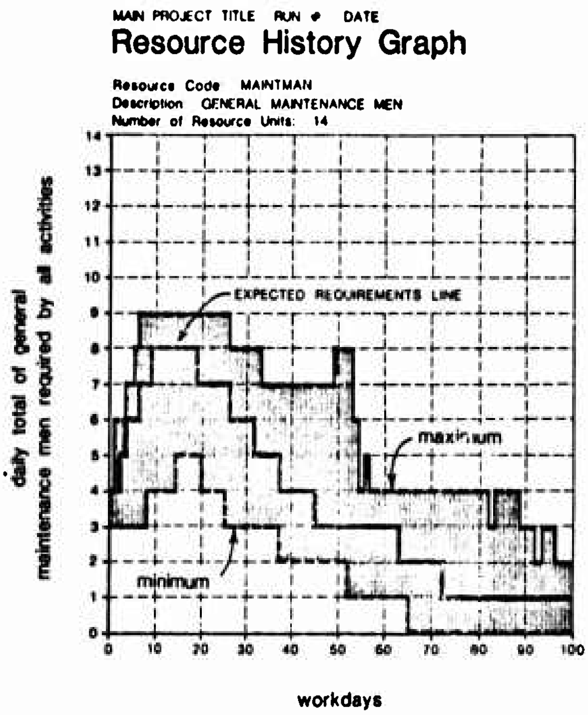

Figure 5. Probabilistic Resource Requirements

E. Cost Risk Analysis

Conventionally, cost estimates are deterministic; that is, costs for the individual line items of a project budget, or for individual project activities of a network, are expressed as single values representing perhaps the "best" 1./ estimate. However, where there is uncertainty, the use of range estimates allows a "cost risk analysis" which combines the uncertainties for the different cost elements and determines the overall range of project costs between minimum and maximum and as well as the risks of overrunning project cost targets.

1./ The practice varies considerably: "best", "most likely", "average", "normal", or no special designation at all may be given to the estimate. On many projects, there is no specific standard discipline applied to the estimating process.

Typical results of a cost risk analysis are shown in Figure 6. The range of total project costs is given together with the probabilities of different cost outcomes between the two extreme values. For example, it is shown that there is a 60% probability of expenditures reaching the amount of $60 million (hence, a 40% probability of exceeding that amount, and by as much as $12.5 million).

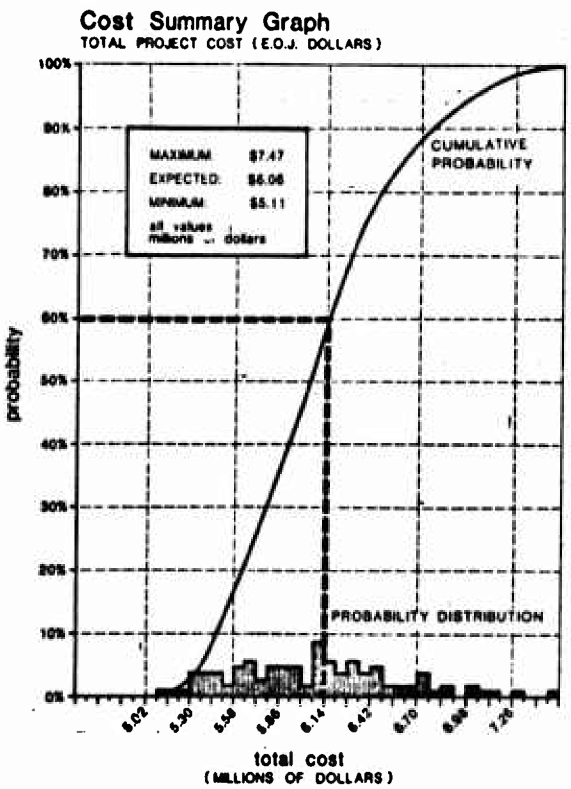

Figure 6. Cost Summary Graph
Total Project Cost (E.O.J. Dollars)

F. Cost/Schedule Analysis

Figure 7 shows a PROMAP V* cost/schedule graph for a typical project. The projection to completion incorporates the uncertainties regarding future events and produces a "projected outcome area" which includes all completion possibilities between the extremes in time and cost performance. A specific cost/schedule target value may be selected as representing any specified level of risk acceptable to management. In Figure 7, the target value shown is the "expected" cost/schedule value, which has an average likelihood of being realized.

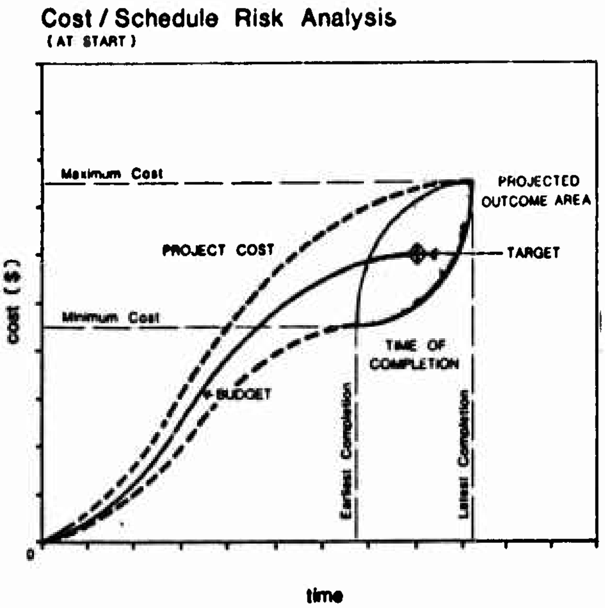

Figure 7. Cost/Schedule Projected Performance

Figure 8 shows the cost/schedule performance at a later stage of the project. Typically, the size of the projected outcome area decreases as certainty replaces uncertainty as the work proceeds. A major task in project risk management is to assure that the expected value of the projected outcome area does not materially deviate from the target value, as is shown in Figure 8.

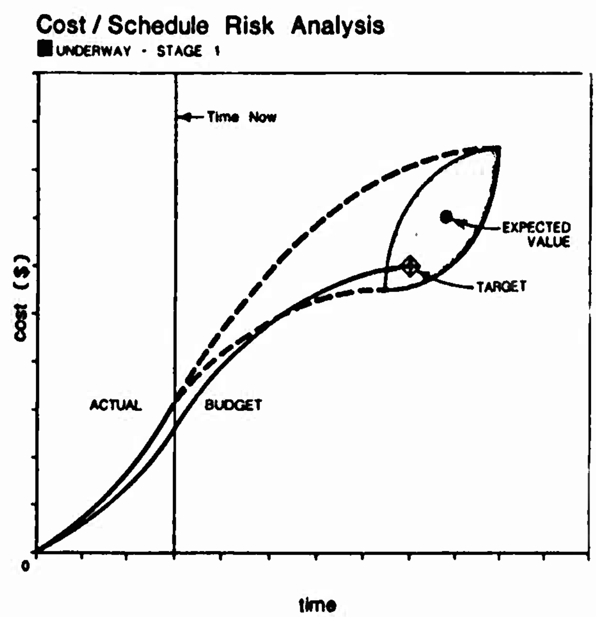

Figure 8. Cost/Schedule Risk Analysis

PROMAP V* provides the diagnostics to allow the project manager to make the specific adjustments to bring the projected outcome area into an acceptable risk range (as shown in Figure 9).

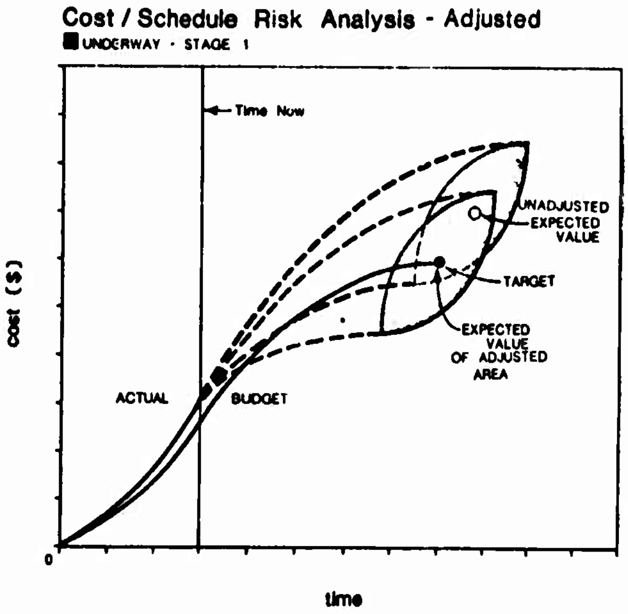

Figure 9. Cost/Schedule Risk Analysis-Adjusted

LESSONS LEARNED

1. Budgets and schedules should be based on the results of risk analyses with "expected" values chosen for the project targets and the use of a contingency allowance or management reserve should be avoided. In practice, the contingency allowance is set-aside to cover the impact of uncertainties on project cost performance. However, project uncertainties generate "minus" as well as "plus" possibilities; events may turn out better than expected. Because the conventional contingency allowance covers just the "pluses", there is no planning to take advantage of the "minus" instances when they occur. Adopting "expected" values and contingency planning will reduce the risks and with effective project risk management, overrun possibilities will be minimized.

2. A baseline risk analysis should be conducted early in the program and updated as appropriate during the pre-award period, assuring the availability of a current risk baseline at the time of source evaluation.

3. The system acquisition RFP should specify that the bidder support its presentation with the following data:

a. Identification of the cost, schedule, and technical risk elements.

b. Description of contingency plans designed to reduce risks on critical technical elements to manageable levels.

c. Results of a risk analysis covering cost, schedule, and technical risks.

d. Explanation of the risk assessment justification supporting the bid price.

e. Description of the bidder's risk management plan covering cost, scheduling, and technical risks, together with the details of procedures and system for implementing the risk management plan.

4. As part of the bid evaluation, the government should compare the bidder's risk analysis results with the government's baseline values. Any significant difference should be analyzed.

5. Once the contract is awarded, the government should continually monitor project risks and risk trends, the latter providing a very sensitive indicator of problems ahead. The periodic reviews of contractor performance should encompass cost, schedule, and technical risk considerations in addition to the standard requirements of DOD I 7000.2.

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